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(54) **REFLECTION-TYPE LIQUID CRYSTAL ELECTRO-OPTICAL DEVICE AND PROJECTION-TYPE DISPLAY  
DEVICE USING THE SAME.**

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(57) A reflection-type liquid crystal electro-optical device includes twisted nematic liquid crystals between two pieces of opposing substrates, linearly polarized incident light enters the liquid crystal layer, and it is reflected and introduced again to the liquid crystal under the circularly polarized condition. The twist angle,  $\Delta n$  and incident polarizing angle are so set that the plane of polarization of the outgoing light is 90 degrees different from that of the incident light (preferably,  $0.33\lambda \leq \Delta n \leq 0.4\lambda$  when the twist angle is  $63^\circ$  and  $0.95\lambda \leq \Delta n \leq 1.15\lambda$  (unit in  $\mu m$ ) when the twist angle is  $193^\circ$ , and the axial direction of the polarized angle and the direction of the liquid crystal molecules are brought into agreement with each other). Since it is allowed to set a large value

$\Delta n$ , thickness of the liquid crystal layer can be increased, an increased margin is obtained from the standpoint of production, the exit light is linearly polarized and permits reduced amounts of optical loss to take place compared with those which emits ovaly polarized light. By setting optimum twist conditions, furthermore, the liquid crystal electro-optical device exhibits sharp electro-optical characteristics with respect to the electric field and produces display maintaining a high contrast.

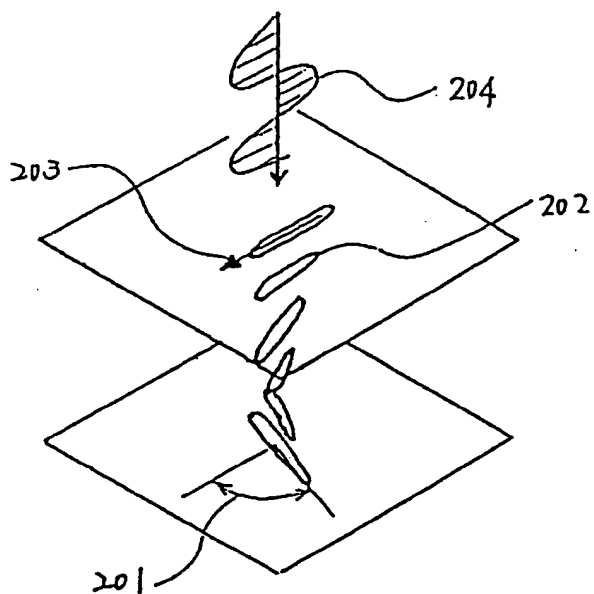


Fig. 2

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see front page

A REFLECTION TYPE ELECTRO OPTICAL DEVICE AND  
A PROJECTION TYPE DISPLAY APPARATUS USING THE SAME

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Technical Field

10 This invention relates to a reflection type electro optical device and a projection type display apparatus using the same. The electro optical device includes a twisted liquid crystal layer and utilizes a birefringence effect of a liquid crystal due to an electric field.

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BACKGROUND ART

20 There have been two kinds of prior art reflection type liquid crystal electro optical devices each of which utilizes a twisted liquid crystal. One uses an optically uniaxial electro optical medium as a  $\lambda/4$  phase plate. The other is described in USP No. 4,019,807 and the JP-A-56-43681, wherein the liquid crystal with a twist angle of  $45^\circ$  to the molecular axis receives a linearly polarized incident light applied slantingly and transmits it as an elliptically polarized light without any refraction under no electric field or subjected to a birefringence under an electric field.

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30 However, in the prior art reflection type liquid crystal electro optical devices, there have been problems in that a tolerance is small for the thickness of a liquid crystal layer and a displaying uniformity is lowered. Also, since the output is an elliptically polarized light, a loss in light increases.

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Accordingly, an object of the present invention is to provide a reflection type electro optical device which makes possible less light amount loss and much margin in manufacture by optimizing the twist angle, a product of a layer thickness and birefringence (hereinafter referred to as  $\Delta nd$ ), and an incident polarized light angle.

Furthermore, another object of the present invention is to provide a reflection type liquid crystal electro optical device in which the dependency of the optical characteristic with respect to an electric field is sharp and the liquid crystal responds sufficiently to a small variation in r.m.s. voltage, whereby a so-called multiplex driving is possible.

Still another object of the present invention is to provide a reflection type liquid crystal electro optical device having a large effective picture element area in comparison with a prior art active element type liquid crystal electro optical device with active elements, for example, thin film transistors (hereinafter referred to TFTs) and metal-insulator-metal elements (hereinafter referred to MIMs).

Further still another object of the present invention is to provide a projection type display apparatus in which the optical arrangement is simple, light utilization ratio is large and color reproductivity is superior.

#### DISCLOSURE OF INVENTION

In order to solve such problems, a reflection type liquid crystal electro optical device according to the present invention is characterized in that in a reflection type liquid crystal electro optical device having a TN liquid crystal layer (hereinafter referred to TN) sandwiched between two plates facing to each other:

1. The TN liquid crystal layer receives a linearly polarized incident light at the reflection surface and turns it into a circularly polarized light at the reflection surface and turns it into a linearly polarized light having a polarization rotated by 90 degrees to that of the direct incident light at the emitting surface after the reflection.
2. The TN liquid crystal layer receives a linearly polarized incident light in parallel or vertically to the molecular axis at the incident surface, and turns it into a linearly polarized light with a polarisation rotated by 90° to that of the incident light at the emitting surface after reflection.
3. The TN layer is conditioned such that the twist angle is approximately 63°, and the product of a layer thickness and a birefringence (hereinafter referred to  $\Delta n d$ ) has the relationship of  $0.33 \lambda \leq \Delta n d \leq 0.4 \lambda$  (about 0.2  $\mu\text{m}$  to 550nm).
4. The TN layer is conditioned such that the twist angle is approximately 193°, and  $\Delta n d$  has the relationship of  $0.95 \lambda \leq \Delta n d \leq 1.15 \lambda$  (about 0.58  $\mu\text{m}$  to 550nm). The conditions of the items 3 and 4 vary in accordance with a wavelength of an incident light to be turned and show the same function.
5. The substrate forming the TN liquid crystal layer includes active elements each of which controls an electric field to drive a liquid crystal. In concrete examples, the active elements may be a TFT matrix, a MIM matrix or a photo conductors.
6. The substrate having the active elements is an untransparent semiconductive substrate.

7. The substrate having the active elements includes a driver circuit on the same substrate to distribute picture element information.

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8. The substrate having the active elements is formed of active elements, signal transmission lines and reflective picture element electrodes.

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9. The substrate having the active elements mounts active elements and signal transmission lines. Interinsulator layers are formed thereon and reflective picture element electrodes are arranged thereon.

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10. The other electrodes form the active elements and are reflective picture element electrodes.

11. A MIM element which functions as the active element is manufactured by the following steps:

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a. depositing one metal thin film for the MIM element on a substrate;

b. processing the metal thin film into a stripe form;

c. forming an inter-layer insulator;

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d. exposing a MIM element forming portion to be selectively oxidized; and

e. mounting the other metal for the MIM element and electrically connecting it to a picture element electrode.

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A projection type display apparatus according to the present invention is characterized in the followings:

12. A reflection type liquid crystal electro optical device includes a TN liquid crystal layer sandwiched by substrates. The layer receives a linearly polarized incident light. The layer turns it into a circularly polarized light

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at the reflection surface and turns it to a linearly polarized light having a polarization rotated by 90° to that of the incident light at the emitting surface after reflection.

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13. The plurality of reflection type liquid crystal electro optical devices includes dichroic elements each of which has a wavelength separation function and a light synthesizing function. The wavelength separation function has the steps of separating a reading light for visualizing a picture image into monochrome components, i.e. into wavelengths corresponding to R, G and B, and illuminating it onto the plurality of the reflection type liquid crystal electro optical devices. The synthesizing step functions to synthesize the light corresponding to the wavelengths of R, G and B reflected by the plurality of reflection type liquid crystal electro optical devices.

14. The dichroic element has two kinds of wavelength selection surfaces which are perpendicular to each other.

15. The plurality of reflection type liquid crystal electro optical devices includes an erect equal magnification imaging optical system which projects an image from image supplying means onto a photo conductor.

As described above, since the device according to the present invention can make the  $\Delta n d$  value larger than that of a prior art device, a large margin in manufacture is obtained with respect to the thickness of a liquid crystal layer. In addition, since the transmitted light is of a linearly polarized light, the light amount loss is small in comparison with that of an elliptically polarized light transmitted from a prior art TN with a twist angle of 45°.

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Fig. 3 is a characteristic of reflectivity (at 550nm) with respect to applied voltages for the device shown in Fig. 1.

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Fig. 4 shows that an incident light twists at 63°.

Figs. 5(a), 5(b) and 5(c) are graphs showing a reflectivity at  $\Delta$ nd and OFF state.

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Figs. 6(a) and 6(b) are graphs showing the relationship between  $\Delta$ nd and reflectivity with an incident polarized light direction as a parameter.

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Fig. 7 is a structural diagram showing a reflection type liquid crystal electro optical device using a PBS as a polarizer.

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Fig. 8 is a cross sectional view of a reflection type electro optical device addressed by TFT elements.

Fig. 9 is a cross sectional view of a reflection type electro optical device of the type written with light.

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Fig. 10 is a structural view of a reflection type electro optical device incorporating peripheral circuits.

Fig. 11 is a cross sectional view of a reflection type liquid crystal electro optical device using MIM elements.

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Figs. 12(a), 12(b), 12(c), 12(d) and 12(e) are flow diagrams for manufacturing.

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Fig. 13 is a cross sectional view of a reflection type electro optical device in a XY matrix form.

Fig. 14 is a structural diagram of a projection type display apparatus.

Fig. 15 is a structural diagram of a reflection type electro optical apparatus using a reflection type electro optical device addressed by CRT.

Fig. 16 is a diagram for a reflection type liquid crystal electro optical device showing the relationship between  $\Delta n d$  and wavelength  $\lambda$  at which the reflectivity has a peak.

# BEST MODE FOR CARRYING OUT THE INVENTION

## EXAMPLE 1

Fig. 1 is a cross sectional view showing a reflection type electro optical device according to the present invention. In this structure, a TN liquid crystal 104 is sandwiched between a transparent substrate 102 and an opposite substrate 103 coated with a reflective film 102. The transparent substrate is required to have no optical anisotropy. In this example, a glass substrate is used. Numeral 105 is a transparent electrode to apply an electric field across the liquid crystal layer. The other electrode is formed of a metal film and acts as the reflective film 102. A reflection decreasing coating 106 is formed over the surface of the transparent conductive electrode and the light input (incident)/output (transmission) surface to suppress the reflection of unnecessary light. Numeral 107 is a spacer to support the substrates. Fig. 1(b) is a cross sectional view showing a reflective film 102 formed over the outside of the opposite substrate 103. In this structure, any material

giving an optical reflection may be used as a reflective film. In Fig. 1(b), the other reference numerals correspond to those of Fig. 1(a).

5 Fig. 2 is a perspective view showing an orientation of a liquid crystal. Fig. 2 shows that the twist angle 201 of a nematic liquid crystal layer is  $63^\circ$ , the product of the birefringence of a liquid crystal and the thickness of a liquid crystal layer is 0.2 (in  $\mu\text{m}$ , hereinafter referred to  $\Delta n d$ ). The incident light is polarized to a linearly polarized light by polarizers which are placed closely to one another. The polarized light is adjusted to a degree that an electric field oscillating surface 204 travels along the director 203 for the liquid crystal molecule 202 at the input side. That is, when the applied voltage is zero, the molecules are oriented in parallel at the interface of the substrate, so as to provide an orientation of  $63^\circ$  between the upper and lower substrates as shown in Fig. 2. This orientation process may be given by rubbing and obliquely evaporating deposition or the like.

Likewise, if a twist angle is  $193^\circ$  and  $\Delta n d = 0.58$ , an incident light linearly polarized turns into an circularly polarized light and after reflection, its polarization is rotated by  $90^\circ$  with respect to that of the incident light at the input side.

Fig. 3 is a characteristic of reflectivity (at 550nm) with respect to applied voltages for the device shown in Fig. 1. The solid line shows a  $63^\circ$  twisted case and the broken line shows a  $193^\circ$  twisted case. First let us explain a case where the voltage is zero. When a linearly polarized light 402 is applied, the locus of the elliptically polarized light is rotated, as shown in Fig. 4. At the reflection surface, the locus is nearly a circularly polarized light

401 and the phase is reflected back after being rotated by 180°. Again the light travels into the liquid crystal layer and transmits out as a linearly polarized light 403. Consequently, its polarization is rotated by about 90° at the output side. For this reason, the light is blocked by the polarizer, so that the reflectivity is decreased (in an OFF state). Next, let us explain a case where a voltage is applied. Molecules of a liquid crystal are reoriented in the direction of an electric field because of the anisotropy in dielectric constant. This removes the birefringence, so that the incident light and the linearly polarized light is reflected back and transmitted out without any change. Hence, any decrease in reflectivity does not occur (in ON state).

Such a change in polarized light occurs in a limited condition. This invention is a result of a careful study of the condition. The liquid crystal layer is needed to have two optical characteristics. One is that a linearly polarized light becomes a circularly polarized light after a single transmission. The other is that the circularly polarized light is reflected and then its polarization is rotated by 90° at the reverse transmission of it. Fig. 4 shows that an incident light twists at 63°.

Figs. 5(a), 5(b) and 5(c) are graphs each showing  $\Delta n_d$  against the reflectivity at OFF state. The parameter is a twist angle of the liquid crystal layer. The polarization of an incident light is met with the directors of the liquid crystal molecules at the incident surface.

The reflectivity in an "ON state" is a constant determined by the transmittance of a polarizer. This exhibits that when the twist angle is approximately 60° and  $\Delta n_d = 0.2$ , the reflectivity becomes nearly zero. A detailed examina-

tion exhibits that the optimum twist angle is  $63^\circ$ . Furthermore, another condition is that the twist angle is  $190^\circ$  and  $\Delta n d$  is 0.6. In a more detailed examination, an optimum condition at a wavelength of 550nm is that the twist angle is  $193^\circ$  and  $\Delta n d = 0.58$ .

As shown in Fig. 4, the locus of the elliptically polarized light becomes a circularly polarized light at the reflection surface and is a linearly polarized light rotated by  $90^\circ$  with respect to that at the light output surface. In comparison with the use of a  $1/4\lambda$  plate, the polarized light enters in this mode with the same direction as the director of a liquid crystal. This mode is characterized by that the light is hard to be subjected to a birefringence a large  $\Delta n d$  to be provided at the same phase change and a small periodic  $\Delta n d$  dependence. This leads to a relatively large thickness of a liquid crystal layer and a large margin in manufacture. This phenomenon seems to be an electrically controlled birefringence in a twist structure (hereinafter abbreviated to TN-ECB).

Also, the  $\Delta n d$  effect functions in a manner similar to the case that a linearly polarized light enters vertically to the director of the liquid crystal. The reason is that  $\Delta n d$  has no polarity.

Figs. 6(a), 6(b) and 6(c) show the relationship between  $\Delta n d$  and the reflectivity as a parameter of angles between the polarizer and the director of the liquid crystal. According to this, there is a condition that the reflectivity is zero when the direction of the polarized light is at  $+30^\circ$ . In this case, the locus of the elliptically polarized light is a circularly polarized light at the reflection surface, as shown in Fig. 4.

Other conditions will be found by taking different parameters. In this case, the minimum  $\Delta n d$  has to be set to control low reflectivity variations due to wavelength. In an extreme small  $\Delta n d$ , since the thickness of the liquid crystal becomes too small, a suitable selection is needed.

Since a reflection type device which has twofold optical distance has a small allowable variation in the thickness of a liquid crystal, there is a problem in manufacturing, whereby a large  $\Delta n d$  is required. This means that the margin is made wider in manufacturing of the elements. In reviewing the above described conditions of  $\Delta n d = 0.2$ ,  $d$  becomes 2,5  $\mu\text{m}$  in a liquid crystal with a typical small  $\Delta n d$  ( $=0.08$ ). On the contrary, in the prior 45° twisted type device mentioned before, the minimum thickness of the liquid crystal is less than 2  $\mu\text{m}$ , thus degrading uniformity and manufacturing yield of the element.

As shown in Fig. 1, the front electrode type device which does not form any picture elements may be used as electrically controlled anti-glaring mirrors for automobiles and light shutters. Particularly, in an application to an electrically controlled anti-glaring mirror, a high reflectivity effect in a transparent state is recognized in comparison with the conventional dichroic pigment type device and the TN type device mounted with polarizing plates on both sides thereof.

The low loss in light amount provides advantageously color images by using a color filter even under a dim illumination, for example, a circumstance with no back light. This results from that the display glows brightly because the lower polarizing light plate and the diffusion type reflection plate are not needed in the conventional TN type reflection liquid crystal element (in a transmission type mode in principle).

As shown by the broken lines in Fig. 3, a sharp optical response to voltage is obtained at a large twist angle of 193°. In this case, the ratio SAT/VTH of an electric field VTH at 90% reflectivity and an electric field SAT at 10% reflectivity is a value of 1.08. Hence, even if an electric field applied across the liquid crystal layer represents small variation in an effective value, the liquid crystal responds sufficiently and makes possible a display with high contrast. This shows that a multiplex driving is capable of being performed with a XY matrix as well as conventional liquid crystal elements.

With the wavelength of a turned light, the conditions described in the present embodiment will be shifted. The ratio is approximately  $\lambda$  (nm)/550 and is roughly proportional to  $\lambda$ . For example, with a twist angle of 193°, the optimum value with respect to a wavelength of 550nm is 0.58. However, if  $\Delta n d = 0.45$  to  $0.75$  or  $0.95\lambda \leq \Delta n d \leq 1.15$  ( $\lambda$  in  $\mu\text{m}$ ), with respect to any wavelength of a visible light ray, the reflectivity is able to be adjusted at its peak value. Also, in order to make the variations in performance at 550nm to an off reflectivity of less than 10%,  $\Delta n d$  is 0.52 to 0.64 and the twist angle of the liquid crystal molecules is 175° to 210°. There are the same conditions at a twist angle of 60°.  $\Delta n d$  ranges from 0.14 to 0.25, or  $0.33\lambda \leq \Delta n d \leq 0.4\lambda$ . The twist angle is 53° to 78° under an off reflectance of less than 10%.

#### EXAMPLE 2

Fig. 7 is a structural diagram of a reflection type liquid crystal electro optical device using a polarizing beam splitter (hereinafter referred to PBS) as a polarizer.

The PBS 701 polarizes linearly a source light 702 to illuminate it onto the liquid crystal panel 703. In the structure of the liquid crystal panel, the light travelling process is the same as that of the embodiment 1. The PBS is a means for detecting a transmitted light and passes out a linearly polarized light which has a shifted angle of 90° with respect to the incident light. For this reason, the output light reflected is stopped with no electric field, and the applied voltage to reflectivity characteristic is symmetric to the ordinate axis of Fig. 3 in the embodiment 1. The transmitted light 704 is projected with the projection optical system 705.

### EXAMPLE 3

Fig. 8 is a cross sectional view showing a reflection type electro optical device addressed by an active matrix. Fig. 8 shows an example arranging MOS transistors at each picture element. Numeral 802 is a picture element electrode, 803 is a liquid crystal layer, 805 is a transparent electrode formed by deposition onto the opposite transparent substrate 806, and 807 is a polarizing plate. The device used here is described in NIKKEI ELECTRONICS (1981) issued on February 16, on page 164. Table 1 shows the detailed specification.



TABLE 1

	Picture element number	220 x 320
	Picture element pitch	80 x 90 $\mu\text{m}$
5	Drive voltage	$\pm 4\text{V}$ (on X side) 12 V (on Y side)
	Display mode	TN-ECB (Electrically controlled birefringence)
10	Thickness of liquid crystal	2.24 $\mu\text{m}$
	$\Delta n$	0.2
	Twist angle	63°
	Substrate	Opaque semiconductor substrate (Si)
15	Reflection surface (Electrode)	Al (with over-coated $\text{SiO}_2$ )
	Process	CMOS
	Picture element transistor	NMOS transistor
20	Gate	Poly-silicon
	Shift register	Static

25 With the use of the reflection display mode, as shown in Fig. 8, the metallization (wirings) and active elements are able to be arranged under the picture elements. This arrangement makes large the aperture ratio (opening ratio) of a picture element (or actual picture element) to the picture element area in spite of the existence of metallization and active elements, thus preventing a decrease in the opening area due to an increasing number of picture elements.

35 Furthermore, in addition to picture image elements and active elements, peripheral driving circuits such as shift registers and the like for distributing picture element information can be incorporated on the same Si substrate.

Fig. 10 is a structural diagram. On the X side, a 320-stage shift register 1001 and a sample holder 1002 are formed and on the Y side, a 220-stage shift register 1003 is formed round the display area 1004. These are formed by a CMOS manufacturing process.

In the transparent type structure, there is a limitation due to the width of wiring, as an aperture ratio is increased. According to the present invention, since metal wiring of low resistance can be arranged under the picture element electrodes without any limitation to a circuit design rule, the drop of a transmission band width due to wiring resistance is prevented.

Also, in comparison with other liquid crystal display modes, the device of the present invention has lower light amount loss than a guest/host type device. The device of the present invention does not require any polarizer and diffusion type reflection plate on the lower side of a prior art TN type reflection liquid crystal element. For this reason, a bright color picture image is obtained under dim light, using color filters.

The thin liquid crystal layer enables to increase the holding capacitance of the liquid crystal layer advantageously.

Furthermore, the reflection type device has an advantage that a heat sink and a temperature controller can be mounted on the opposite surface because the light input surface acts as the light output surface.

A sharp threshold characteristic to electric field is obtained by varying the twist conditions, so that a display with a high contrast is possible without making the swit-

ching ratio of the transistor large. In the embodiment, MOS transistors are used on a Si substrate. However, TFT transistors may be employed in place of the MOS transistors.

5      **EXAMPLE 4**

Fig. 9 is a cross sectional view of a reflection type electro optical device which is written by means of light. A photo conductive layer 901 varies its resistance by means of light to control the electric field across the liquid crystal layer 902. Numeral 903 is a reflection mirror in a dielectric mirror structure. Numeral 904 is a transparent electrode to apply an electric field. Such device is disclosed in JP-A-56-43681 and the paper J. Opt. Soc. Am., Vol.70, No. 3,287 (1980). However, the device according to the present invention uses two conditions: one being  $\Delta n$  of 0.2 and a twist angle of  $60^\circ$  and the other being  $\Delta n$  of 0.53 and a twist angle of  $180^\circ$ . This enables high of reflectivity in an optimum arrangement of a PBS.

20      Table 2 shows a detailed constitution. In the embodiment according to the present invention, an intrinsic amorphous silicon with a small amount of boron is used as a photo conductive layer. However, a PIN structure may be used. Also, CdS, Se, OPC, monocrystalline silicon, BSO or the like is a good material for the photo conductive layer.

Varying the twist conditions makes the threshold characteristics sharp and enables a high contrast display even if the switching ratio of the photo conductor is small.

30

TABLE 2

	Photo conductor	a-Si by plasma CVD process (A small amount of boron doped intrinsic)
5	Dielectric mirror	Si/SiO <sub>2</sub> dielectric multi-layer mirror
	Liquid crystal	TN-ECB (Electrically controlled birefringence) turned at 550nm
10	Polarizing means	PBS
	Transparent substrate	Corning 7059 glass
	Transparent electrode	ITO (Indium Tin Oxide) Spattered film
15	trode	

## EXAMPLE 5

Fig. 11 is a cross sectional view of a reflection type electro optical device using MIM elements. A liquid crystal 1104 is sandwiched between the MIM substrate 1102 and the opposite substrate 1103. The MIM substrate 1102 mounts a reflective picture element electrode 1101. Numeral 1105 is a transparent electrode for applying an electric field to the liquid crystal layer. The electrode 1105 is in the form of a stripe corresponding to the picture element size. The MIM substrate comprises a signal transmission wiring 1107 in line form over a substrate 1106, a MIM element 1108 of a thin insulator formed on a portion of the wiring 1107 and a picture element electrode 1101 electrically connected to the MIM element.

The picture element electrode also can act as the other metal thin film of the MIM element and a reflective film of an electro optical element. Numeral 1110 is a anti-reflection coating and 1111 is a polarizing element.

Table 3 shows a more concrete configuration.

TABLE 3

5	GENERAL	
	Picture element number	220 x 320
	Picture element pitch	80 x 90 $\mu$ m
	MIM SUBSTRATE	
	MIM element	Ta-Ta <sub>2</sub> O <sub>5</sub> -Cr
10		Ta <sub>2</sub> O <sub>5</sub> 500 Å
	Oxidation process	Wet anodizing process
	Signal transmission wiring	Ta
	Picture element electrode	Cr reflection film
	Layered insulator	Polyimide
15	DISPLAY MODE	TN-ECB (Electrically controlled birefringence)
	Liquid crystal layer	
	thickness	2.4 $\mu$ m
	$\Delta n d$	0.2
20	Twist angle	63°

With the use of such a reflective display mode, the wiring and the MIM elements can be mounted under the picture element electrodes, as shown in Fig. 11. This structure can make large the aperture ratio (opening ratio) of an actual picture element electrode to a picture element area in spite of the existence of wiring and active elements, thus preventing a decrease in an aperture ratio due to an increase in the picture element number.

In the transparent type device, the wiring width is limited to an increase of an aperture ratio. However, in this invention, the transmission range is not degraded due to the wiring resistance because a thick metal wiring can be arranged under the picture electrode.

Also, the element mounting substrate does not use three terminal elements such as TFTs which need two or more crossed wirings, but uses only no crossed wiring, whereby a defect due to a short circuit between crossed wirings does not occur.

The thin thickness of a liquid crystal layer increases advantageously the holding capacitance of the liquid crystal layer. An intrinsic semiconductor which has a larger band gap than that of a conventional semiconductor such as Si is used to provide essentially good light tolerance. The reflection type structure can seal completely a semiconductor portion of the element to incident light to further improve light tolerance.

Furthermore, the device according to the present invention provides lower loss in light amount in comparison with the guest host type device. The device of this invention also has an advantage that a bright color image is obtained under dim illumination using color filters because any polarizer and diffuser which are put under the substrate and used for a prior art TN type reflection liquid crystal element (using a transparent mode in principle) are not used.

A sharp threshold characteristic to electric field is obtained by varying the twist condition so that a display with high contrast is provided without making the switching ratio of a MIM element large.

As shown in Fig. 11, a reflection type display device is formed through a peculiar manufacturing process and has a different structure from a conventional MIM type element. Next, this manufacturing process will be explained. Figs.

12(a), 12(b), 12(c), 12(d) and 12(e) are diagrams showing manufacturing steps.

5 a.) A thin film 1201 of Ta, or one metal for a MIM element, is deposited on the substrate 1202 (see Fig. 12(a)).

b.) The Ta thin film is photo-etched into a stripe pattern (see Fig. 12(b)).

10 c.) A layered insulator 1203 is coated (see Fig. 12(c)). In the example, a photo sensitive polyimide is spin-coated, but an inorganic insulator may be used instead.

15 d.) A MIM element forming region is exposed with a photo-etching process to be selectively anodized. Here, a  $Ta_2O_5$  1204 of about 500 Å is formed with a wet process (see Fig. 12(d)).

20 e.) Cr 205, or another metal for the MIM element, is deposited in vapor phase, and then a picture element electrode is formed by photo etching (see Fig. 12(e)).

25 In this embodiment, in order to simplify the process, Cr, one metal for a MIM element, is used for a picture element electrode. In case of a need for a higher reflectivity, a film of Al, Ag or the like may be used effectively for the picture element electrodes.

30 Furthermore, in the patterning for the signal transmission line, the rule is eased to simplify the process.

#### EXAMPLE 6

35 Fig. 13 shows a simple X-Y matrix type liquid crystal panel using the reflection type liquid crystal electro optical device of the present invention. Numeral 1301 is a transpa-

rent substrate such as glass or the like, 1302 is a transparent electrode such as ITO, 1303 is an Al electrode on the opposite substrate 1304. Like the reflection type liquid crystal electro optical device shown in Fig. 1, the surfaces of the transparent 1302 and the Al electrode 1304 are processed for orientation and a nematic liquid crystal is held by means of a spacer therebetween. The condition as to the thickness of the liquid crystal layer and to the twist angle of the liquid crystal molecules is the same as that of the 193° TN described in the example 1. Like a transparent type simple matrix liquid crystal panel, the liquid crystal molecules with a small twist angle bring a low contrast when a number of picture elements are operated at a high duty drive operation. However, according to the reflection type liquid crystal electro optical device shown in the present embodiment, good contrast is provided because of its sharp threshold characteristics with respect to electric field.

#### EXAMPLE 7

Fig. 14 is a structural diagram showing a projection type display apparatus using a plurality of a reflection type liquid crystal electro optical device according to the present invention.

The reflection type liquid crystal electro optical devices 1401, 1402 and 1403 may be formed like those shown in the embodiments 1, 2, 3, 5 or 6. Here, a reflection type liquid crystal electro optical device using the transistors described in the embodiment 3 as a driving active element is utilized.

Numeral 1410 is a signal source for driving a reflection type liquid crystal electro optical device. After an image video signal is demodulated and then separated into an R



signal, a B signal and a G signal, each of the signals is supplied to a corresponding one of the reflection type liquid crystal electro optical devices to display a monochrome image. As described in the embodiment 1, while a light applied on the liquid crystal layer is reflected back at the reflective film, it is subjected to retardation during transmission by the liquid crystal to form a picture image. In this way, a picture image corresponding to the R, G and B signals of a picture image to be displayed is formed on the corresponding one of the reflection type liquid crystal electro optical devices 1401, 1402 and 1403. Numerical 1413 is a readout light source for visualizing the above picture image information, and for example a Xenon lamp, Halogen lamp, Metal halide lamp, or the like. The readout light source with a reflector provides a high light utilization efficiency. An infrared filter may be added to isolate heat absorbed in the reflection type liquid crystal electro optical devices and other optical components. An ultra violet cut filter may be added to prevent the degradation of the liquid crystal in a reflection type liquid crystal electro optical device. The readout light generated from the readout light source 1413 is separated into P and S polarized light with a polarizing beam splitter 1414. Fig. 14 shows that a S polarized light component reflected by the polarizing beam splitter is used for displaying. In the display of the P polarized light component, the above mentioned readout source may be replaced in position by a projection lens to be described later. The replacement is also applicable to the following apparatus. The polarizing beam splitter 1414 is desirable to have good polarization characteristics over a whole range of visible light and to maintain sufficiently a whiteness of the light generated out of a light source. A light passed through the polarizing beam splitter 1414 enters into the dichroic prism 1415 acting as a dichroic element, and is separated into three

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colors RGB. The monochromatic light is illuminated onto a reflection type liquid crystal electro optical device. The dichroic prism 1415 comprises four rectangular prism blocks combined with each other. A dielectric multi film is coated on the contact surface of each block and acts as two kinds of perpendicularly crossed wavelength separation surfaces. The dielectric multi film formed on one contact surface is designed so as to reflect a light of a wavelength corresponding to red (R) in white light and so as to pass the remaining wavelengths of it. The dielectric multi layer formed on the opposite surface is designed so as to reflect a light of a wavelength corresponding to blue (B) in the white light and so as to pass the remaining wavelengths of it. Hence, the light passed through the polarizing beam splitter 1414 is separated in accordance with the wavelengths by the dichroic prism 1415 and the reflected red (R) and blue (B) lights and the transmitted green (G) light are separately illuminated to the electro optical devices. As described before, the picture image light is specially modulated with the electro optical devices 1401, 1402 and 1403 which form picture images corresponding to the colors RGB, and enters into the dichroic prism. The light which contains picture image information of green (G) passes through the dichroic prism without change, and the light which contains picture image information of red (R) and blue (B) are reflected by the dielectric multi film on the dichroic prism. Then, the RGB light is synthesized and again is applied onto the polarizing beam splitter. In the synthesized light which is applied onto the polarizing beam splitter, only a light component with a 90° rotated polarization with respect to the incident light which is applied onto the liquid crystal electro optical device passes to project an image on the screen 1417 with the projection lens 1416.

Fig. 14 shows an example of an arrangement of a very compact projection optical apparatus. Instead of the dichroic prisms, dichroic mirrors in a parallel or vertical position may be used for the RGB separation and synthesis. In this case, the reflection type liquid crystal electro optical devices can provide a good advantage to realize a unique projection type display apparatus.

As described in the embodiment 1, since both the polarizer and the analyzer can be used as a polarizing element. A polarizing plate can be arranged in place of the PBS of Fig. 4 and the optical system can be further simplified by adding means for separating into a light source light and a transmitted light (for instant schlieren stop means).

In an electro optical device used for the projection type display device shown by the present embodiment, the TN layer is used under conditions of a twist angle of  $60^\circ$  and  $\Delta n_d = 0.2$ , as well as a twist angle of  $193^\circ$  and  $\Delta n_d = 0.58$ . With respect to the wavelength of a light monochromed with a dichroic prism, the  $\Delta n_d$  of each of the reflection type liquid crystal electro optical devices is optimized. Furthermore, a detailed study on the conditions of the  $193^\circ$  TN showed clearly the relationship between a wavelength with a peaked reflectivity and  $\Delta n_d$ , as shown in Fig. 16.

In a reflective liquid crystal electro optical device with liquid crystal molecules of which the twist angle is set at  $193^\circ$ , Fig. 16 shows the reflectivity in case of no electric field measured with a polarizing beam splitter. In Fig. 16, the solid line is a plot of a wavelength with respect to  $\Delta n_d$ , with the wavelength providing a peaked reflectivity in case of no electric field. The center wavelength  $\lambda$  separated with the dichroic prism shown in the present embodiment is 630 nm in the liquid crystal reflective electro op-

tical device 1401 for red. In the device 1402 for green,  $\lambda$  is 550nm. In the device 1403 for blue,  $\lambda$  is 480nm. Hence, if  $0.95\lambda \leq \Delta n d \leq 1.15\lambda$ , the influence on a color intensity of a picture image formed may be ignored. If  $\Delta n d = 0.65$  in the device 1401,  $\Delta n d = 0.58$  in the device 1402, and  $\Delta n d = 0.50$  in the device 1403, each of the liquid crystal electro optical devices provides the highest reflectivity to the wavelength of a light applied and can display improved picture image in color reproductivity.

The broken line of Fig. 16 shows the relationship between a  $\Delta n d$  and a wavelength with a peaked reflectivity, in a prior art liquid crystal reflective liquid optical device using liquid crystal molecules with a twist angle of  $45^\circ$ . In comparison with the reflection type liquid crystal electro optical device with the characteristics shown by the solid line, the above device has a peak wavelength for the reflectivity sensitive with respect to the  $\Delta n d$  variations, and has a gap margin for a liquid crystal layer for optimizing the reflection type liquid crystal electro optical device in accordance with the separation characteristics of the dichroic prism, whereby the color intensity of a displaying picture image is degraded. On the other hand, in the reflection type liquid crystal electro optical device according to the present invention, a variation in the peak wavelength for the reflectivity is moderate with respect to the  $\Delta n d$  variations, so that the optimization is easy.

#### EXAMPLE 8

Fig. 15 is a structural diagram showing a projection type display apparatus using a plurality of a reflection type liquid crystal electro optical devices addressed by a photo conductor.

5 The light recording type reflective liquid crystal electro optical devices 1501, 1502 and 1503 include a liquid crystal layer and a photo conductive layer and form optically a picture image. They are shown in the embodiment 4, Fig. 9 and Table 2, respectively.

10 Numerals 1504, 1505 and 1506 are erect equal magnifying projection optical systems each of which couples optically a reflection type liquid crystal electro optical device with the screens of cathode ray tubes 1507, 1508 and 1509 as picture image supplying means. In the concrete example, a rod lens array of which a plurality of refractive index distribution type rod lenses is arranged in plane is used. Instead of the rod lens array, coupling means using an erect equal magnifying projection optical system may be used which comprises a plurality of micro lens arrays. The lens array is formed of a plurality of horizontally arranged micro lenses each of which has refractive index distribution characteristics. Also, a fiber with a plurality of holes of a small diameter may be coupled with a fiber micro plate arranged horizontally. Numerals 1510, 1511 and 1512 are power supplies for driving respective reflection type liquid crystal electro optical devices 1501, 1502 and 1503. The cathode ray tubes 1501, 1502 and 1503 display separately picture images based on picture image RGB signals from a video signal source (not shown). The picture image is guided to respective reflection type liquid crystal electro optical devices by the above mentioned rod lens array to project onto a photo conductive layer. After different video signals supplied to different cathode ray tubes demodulate a common video signal in color to separate into RGB signals, each color is supplied to a respective cathode ray tube and a monochrome picture image of a component of each of the RGB signals is displayed on each of the cathode ray tubes. An incident light on the photo conductive layer va-

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ries its impedance, so that the impedance ratio between the photo conductive layer and the liquid crystal layer varies. As a result, almost all the voltage is applied to the photo conductive layer in the dark state. In the illuminated state, the voltage is applied to the liquid crystal layer, and the liquid crystal changes its orientation. As described in the embodiment 1, while the light irradiated through the liquid crystal layer is reflected back by a dielectric multi layered mirror and emitted out, it is subjected to retardation to form a picture image. In this way, the reflection type liquid crystal electro optical devices 1501, 1502 and 1503 display picture image information corresponding to the RGB signals of a picture image to be displayed, respectively. The projection optical system, which is the same as that in the embodiment 7, comprises a readout light source 1513 for visualizing the above mentioned picture image information, a polarizing beam splitter 1514, a dichroic prism 1515 as a dichroic element, a projection lens 1516 and a screen 1517.

In the electro optical system using the projection type display device shown in the present embodiment, the TN layer is used under the conditions described in the embodiment 7.

The present embodiment uses a cathode ray tube as means for writing a picture image onto the reflection type liquid crystal electro optical device. However, a laser beam modulated by a video signal may be used for writing into a photo conductive layer by scanning in two dimensions a polygon scanner, an acoustic optical modulator, a galvano scanner or the like. The present invention is applicable to a wide variety of reflection type photo control apparatus in addition to the present embodiments.

INDUSTRIAL APPLICABILITY

5 In comparison with a prior art device, the above described present invention allows a large  $\Delta n d$  value and a large margin to the thickness of a liquid crystal layer in manufacture. Also, the use of a nearly linearly polarized light enables effectively low loss in light amount.

10 Also, since signal transmission lines and active elements can be arranged under the picture electrodes, the aperture ratio does not decrease due to the picture element driving means (such as TFTs), whereby the light amount loss is effectively decreased.

15 The reflective display mode enables the use of an untransparent silicon substrate and can effectively integrate a peripheral circuit such as a driver circuit. This leads to a simple assembly, low cost and improved reliability. Also, since signal transmission lines and active elements can be arranged under the picture element electrodes, the light  
20 resistance and thermal conduction are effectively improved.

25 Furthermore, since signal transmission lines and active elements can be arranged under the picture element electrodes, the minimum dimension rule in manufacture can be related to adopt effectively a simplified manufacturing process.

30 The variation in the twist condition allows a control of the threshold characteristics with respect to electric field. The sharp transition of the threshold enables a secure response to a small change in the effective voltage value, a high duty driving of a simple matrix type liquid crystal panel, and a high contrast display of an active element type liquid crystal panel with a small switching  
35 ratio of a transistor or a MIM element. Contrary, a modera-

ted threshold value enables the half tone display and eases handling a tone signal such as a video signal.

5 The low loss in light amount provides an advantage that a color picture image is obtained under dim illumination, for example, an atmosphere with no back light, by using a color filter. This results from that, there is no need of any polarizing plate and diffusing plate used in a prior art TN type reflective liquid crystal element provides bright display.

10 According to the present invention, since a peaked reflectivity of the liquid crystal electro optical device can be adjusted readily by turning the wavelength of a monochrome light with a dichroic element, a color intensity of a display picture image is improved, and the obtained picture image is close to natural color. Also, an optimization in the twist angle of liquid crystal molecules improves the contrast, the utilization of light flux of a light source

15 light and the picture image quality.

20 In addition, the use of a large opening ratio improves the light flux utilization. The improved light flux utilization can decrease the light amount of a light source, and decreases a temperature rise of a liquid crystal electro optical device due to an incident light. Furthermore, this increases effectively the reliability and operational life of the liquid crystal electro optical devices and projection type display systems. The use of the reflection type

25 liquid crystal electro optical device enables the spaces for illumination system and projection system to be shared, and can realize a compact optical system.

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CLAIMS

1. In a reflection type liquid crystal electro optical device having a twisted nematic (hereinafter referred to as TN) liquid crystal sandwiched between two substrates faced to each other, the improvement comprising said TN liquid crystal layer turning a linearly polarized incident light into a circularly polarized light at a reflection surface and turning the circularly polarized light to a linearly polarized light having a polarization rotated by 90° with respect to that of said incident light at a transmission surface after the reflection.
2. A reflection type liquid crystal electro optical device according to claim 1, wherein said TN liquid crystal layer receives said linearly polarized incident light in parallel with or perpendicular to the molecular axis at the incident surface of said TN liquid crystal and turns it into a direct polarized light having a polarization rotated by 90° to that of the incident light at the transmission surface after the reflection.
3. A reflection type liquid crystal electro optical device according to claim 1, wherein said TN liquid crystal layer has a twist angle of approximately 63° and the product (hereinafter referred to  $\Delta nd$ ) of the thickness and birefringence is  $0.33\lambda \leq \Delta nd \leq 0.4\lambda$  (wavelength  $\lambda$  in  $\mu\text{m}$ ).
4. A reflection type liquid crystal electro optical device according to claim 1, wherein said TN liquid crystal layer has a twist angle of approximately 193° and  $\Delta nd$  has the relationship of  $0.95\lambda \leq \Delta nd \leq 1.15\lambda$ .
5. A reflection type liquid crystal electro optical device according to claim 1, wherein said substrate f r

sandwiching the TN liquid crystal layer mounts active elements which control an electric field to drive the liquid crystal.

5           6. A reflection type liquid crystal electro optical device according to claim 5, wherein said substrate mounting the active elements is an untransparent semiconductor substrate.

10           7. A reflection type liquid crystal electro optical device according to claim 5, wherein said substrate mounting the active elements has a driver circuit for distributing picture element information on the same substrate.

15           8. A reflection type liquid crystal electro optical device according to claim 5, wherein said substrate including the active elements further comprises signal transmission lines and reflective picture element electrodes.

20           9. A reflection type liquid crystal electro optical device according to claim 5, wherein said active element mounting substrate comprises active elements, signal transmission lines, a layered insulator formed on the lines and a reflective picture element electrode formed on the insu-  
25           lator.

          10. A reflection type liquid crystal electro optical device according to claim 5, wherein one electrode of the active elements is a reflective picture element electrode.

30           11. A reflection type liquid crystal electro optical device according to claim 5, wherein said active elements are MIM elements, said MIM element manufacturing process comprising the steps of:

a) depositing a metal film for the MIM element on the substrate;

b) processing said metal film into stripes;

c) arranging a layered insulator;

5 d) exposing a portion for forming the MIM element to be oxidized; and

e) arranging another metal film for the MIM element, and then forming a picture element electrode to be coupled electrically.

10

12. In a projection type display apparatus for displaying a color image using a plurality of reflection type liquid crystal electro optical devices, each of said liquid crystal electro optical devices comprising a TN liquid crystal layer which receives a linearly polarized incident light, turns said incident light into a circularly polarized light at a reflection surface, and after reflection, turns it into a linearly polarized light having a polarization rotated by 90° to that of said incident light at a transmission surface.

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13. A projection type display apparatus according to claim 12, further comprising a dichroic element which provides wavelength separation means and light synthesizing means, said wavelength separation means separating a read-out light for visualizing picture images formed on said plurality of reflection type liquid crystal electro optical devices, into different wavelengths corresponding to R, G and B lights, respectively, said light synthesizing means synthesizing lights corresponding to the wavelengths of the R, G and B lights with said plurality of said reflection type liquid crystal electro optical devices.

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14. A projection type display apparatus according to claim 13, wherein said dichroic element has two kinds of

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wavelength selection surfaces perpendicularly intersecting to each other.

- 5        15. A projection type display apparatus according to claim 12, further comprising an erect equal magnification imaging optical system which projects an image from image supplying means onto the photo conductor.

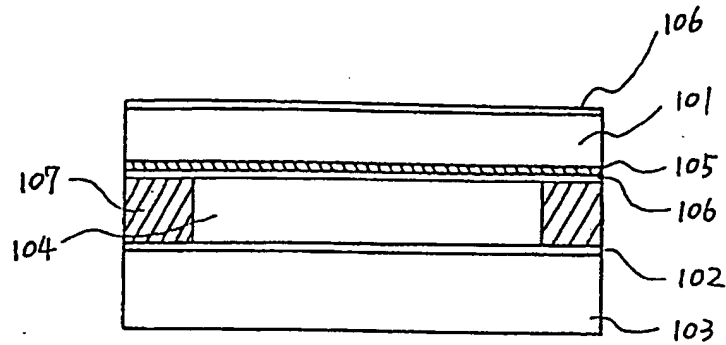


Fig. 1 (a)

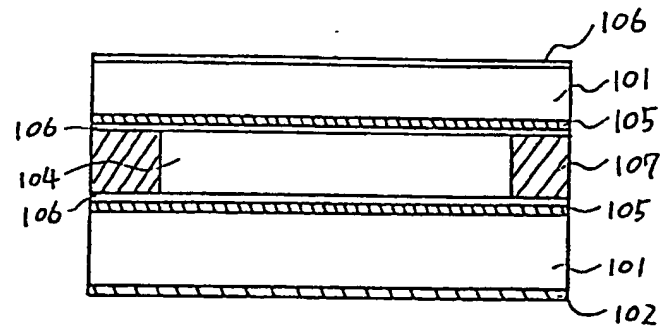


Fig. 1 (b) )

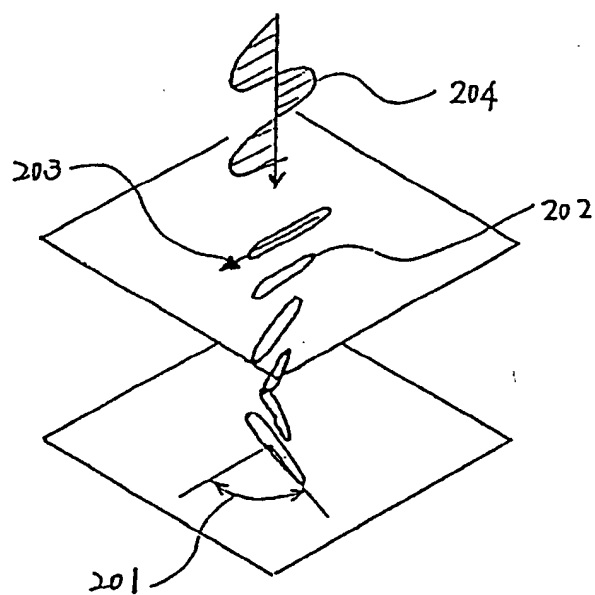


Fig. 2

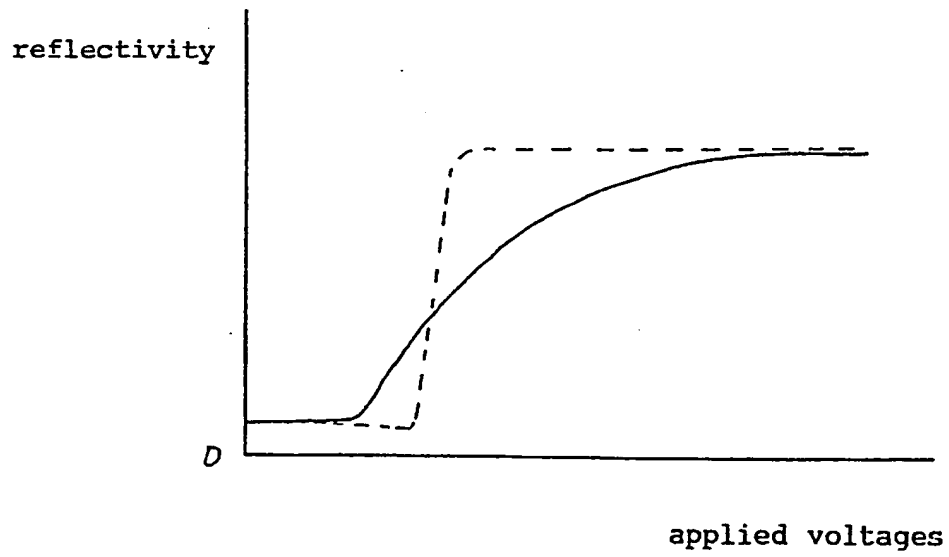


Fig.3

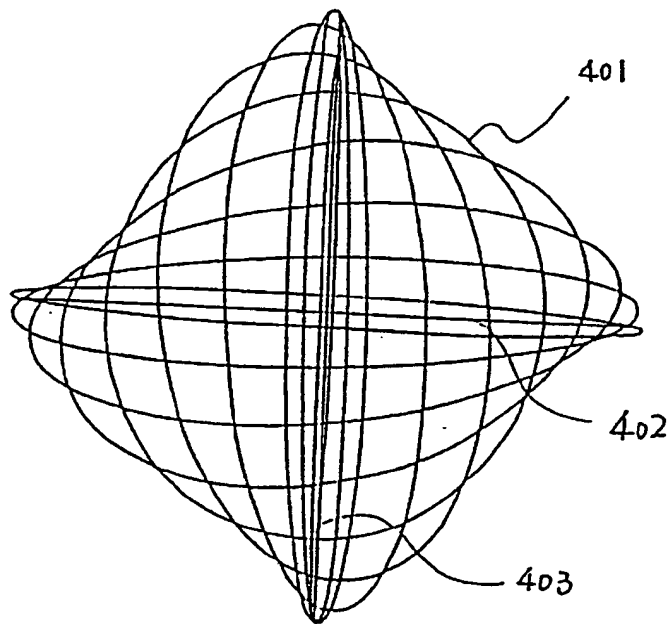


Fig. 4



reflectivity

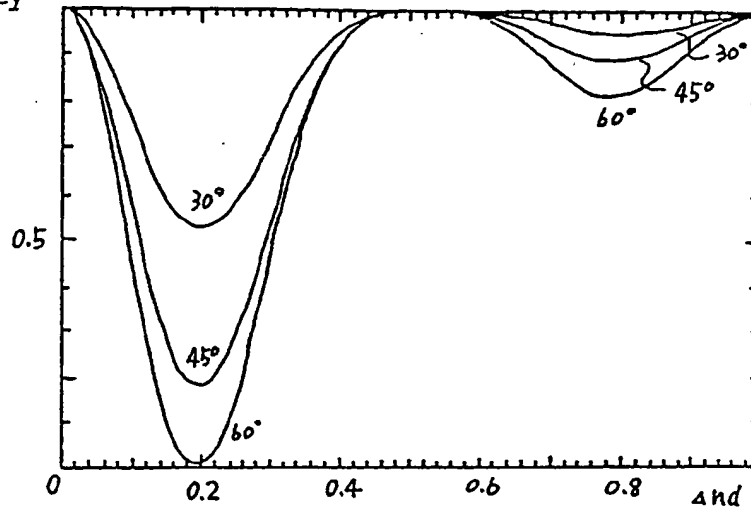


Fig. 5 (a)

reflectivity

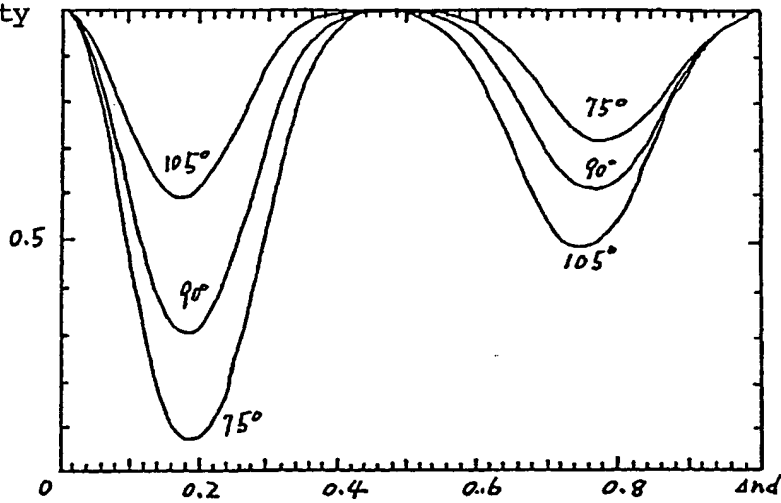


Fig. 5 (b)

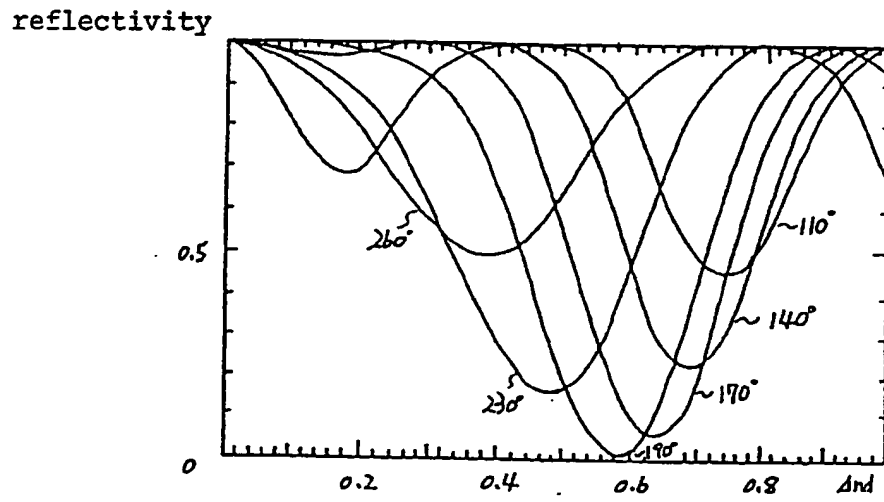


Fig. 5 (c)

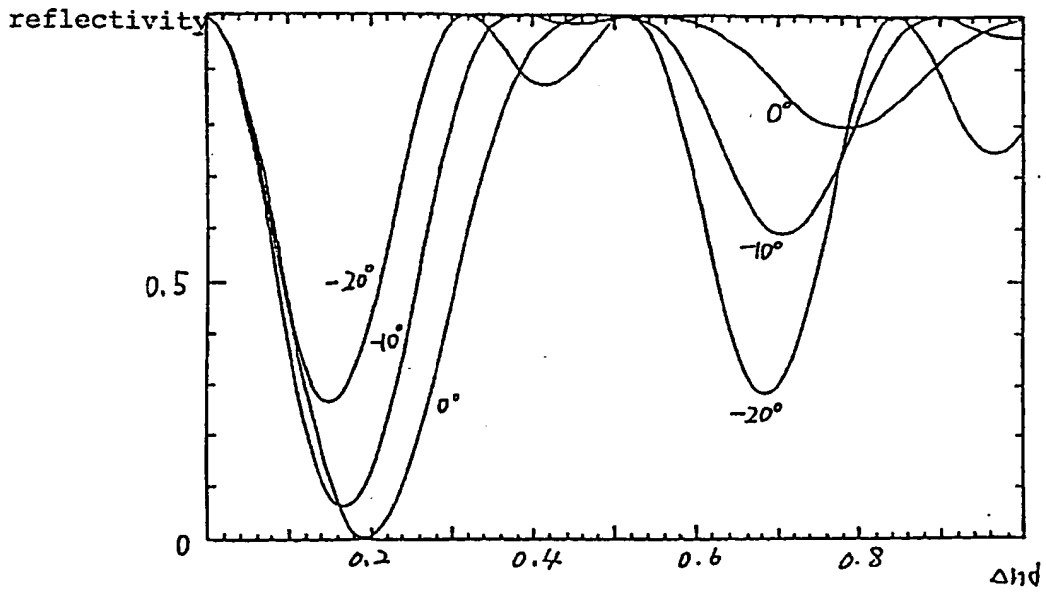


Fig. 6 (a)

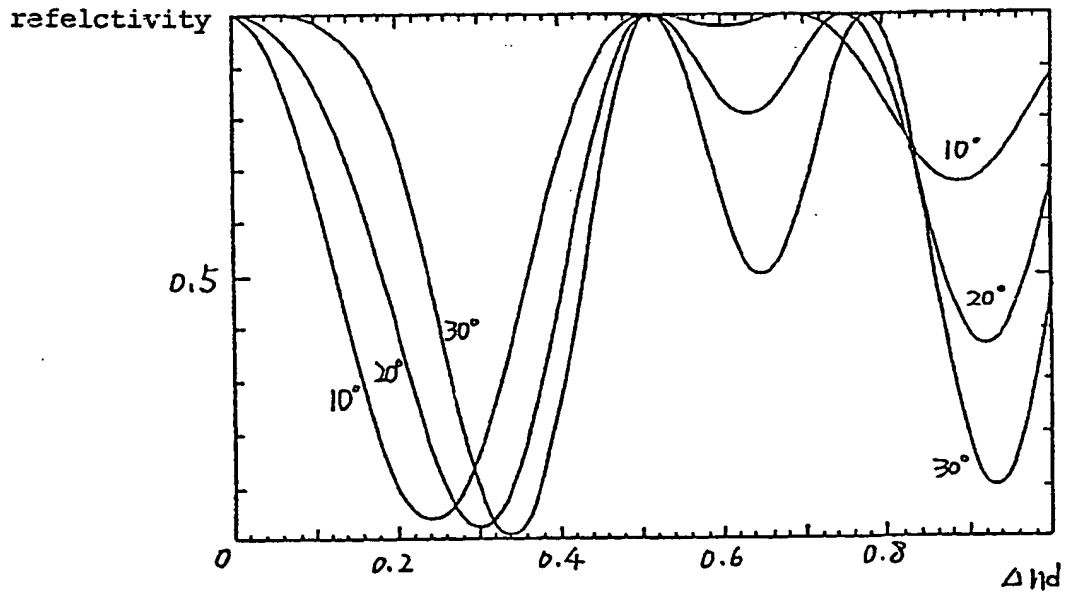


Fig. 6 (b)

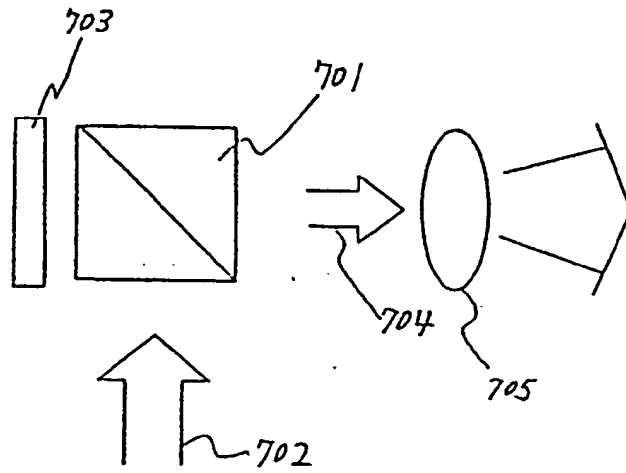


Fig. 7

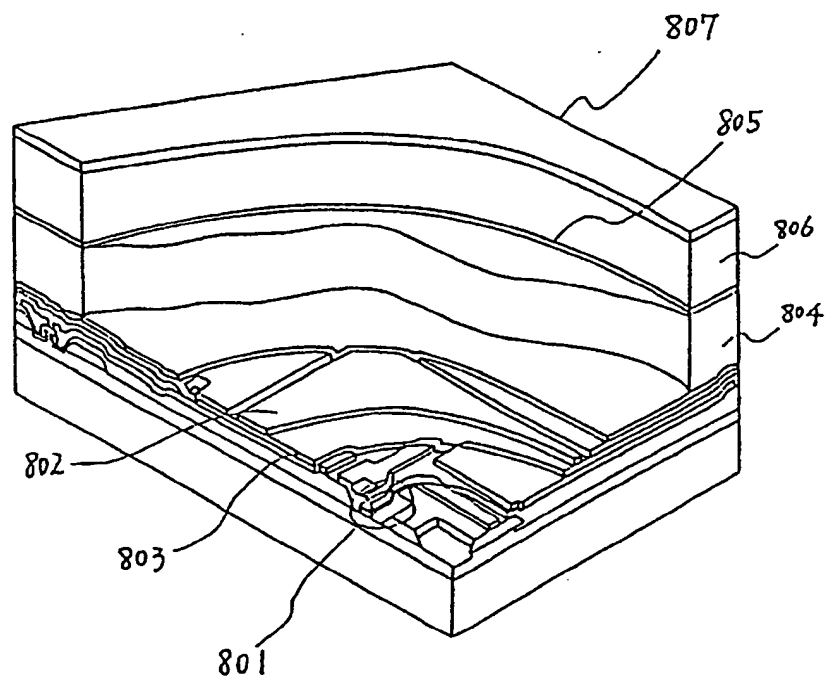


Fig. 8

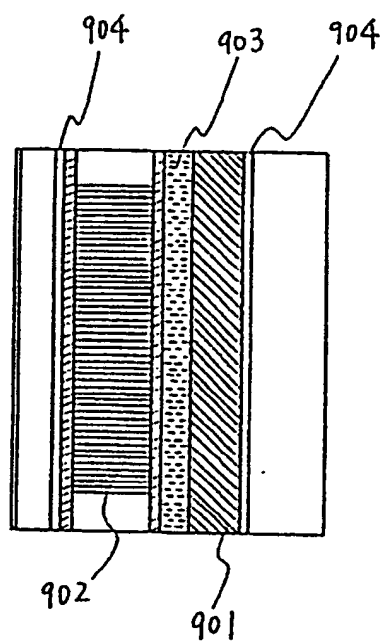


Fig. 9

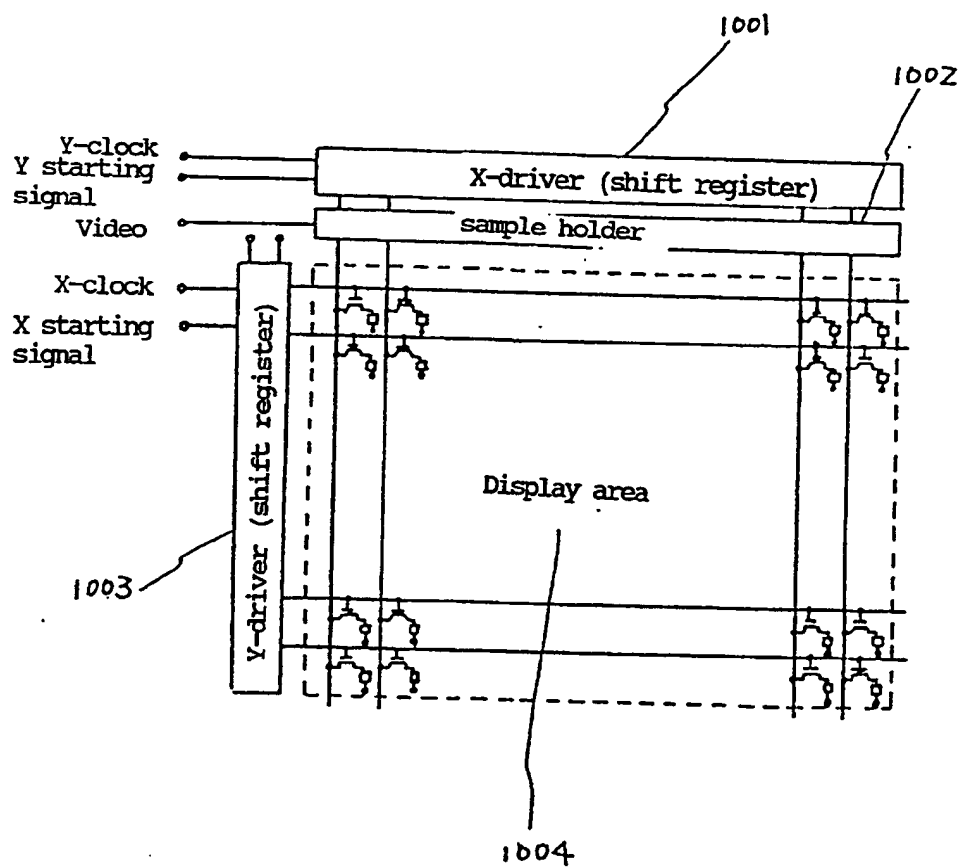


Fig. 10

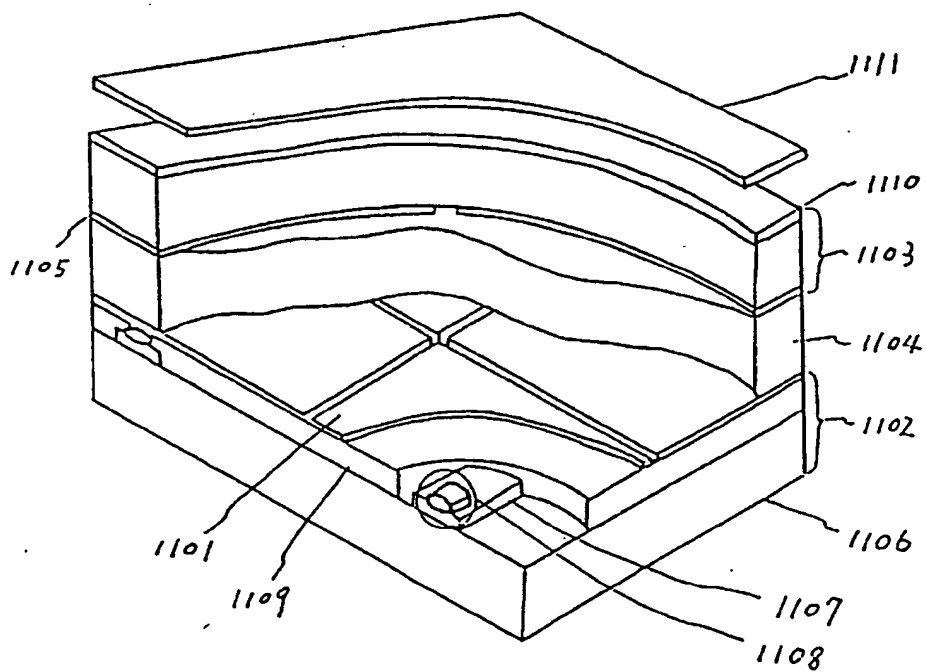


Fig. 11





Fig. 12 (a)

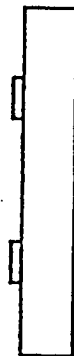


Fig. 12 (b)

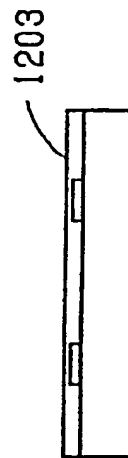


Fig. 12 (c)

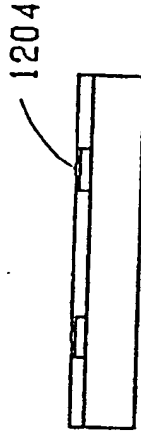


Fig. 12 (d)



Fig. 12 (e)

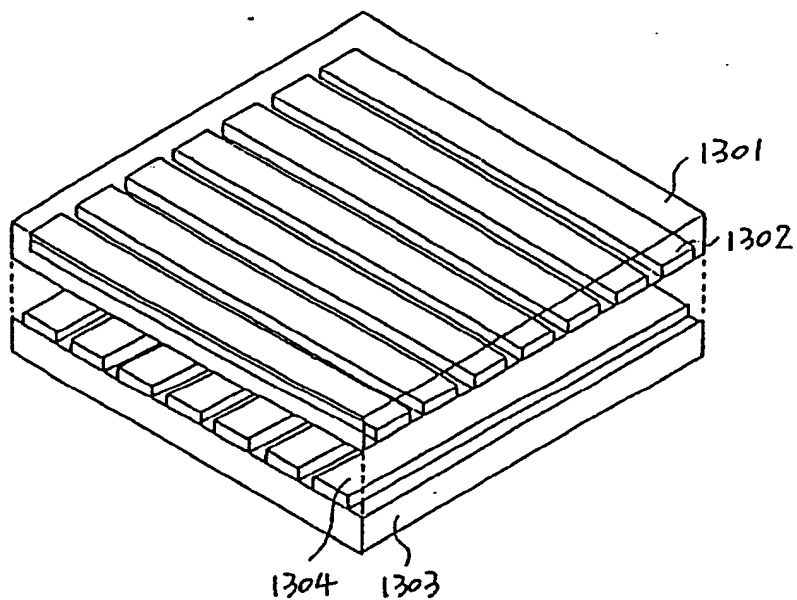


Fig. 13

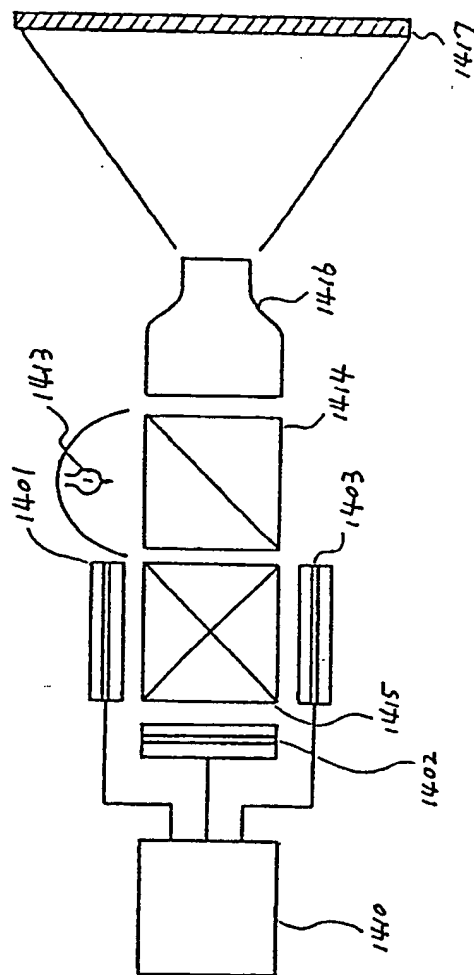


Fig. 14

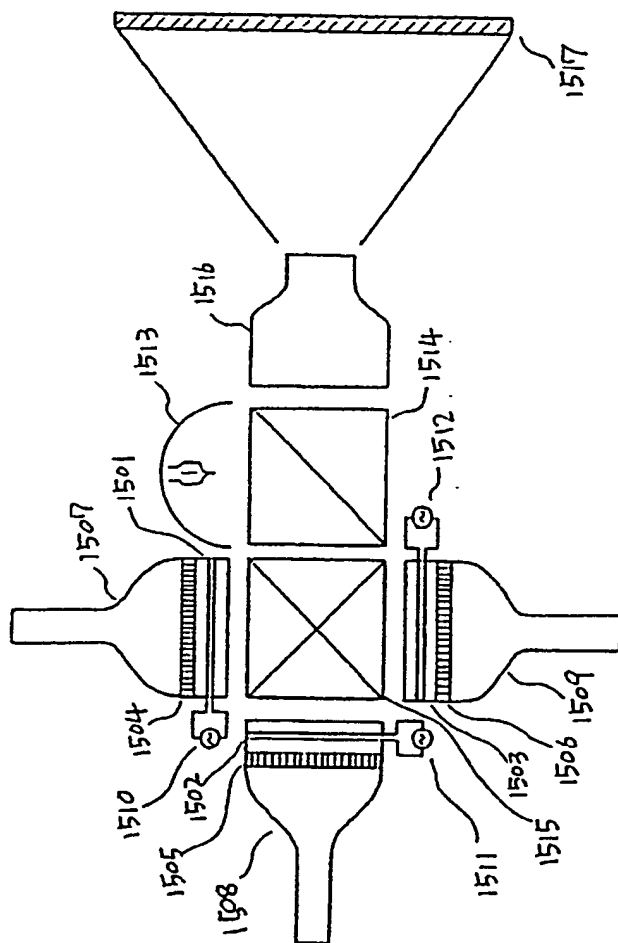


Fig. 15

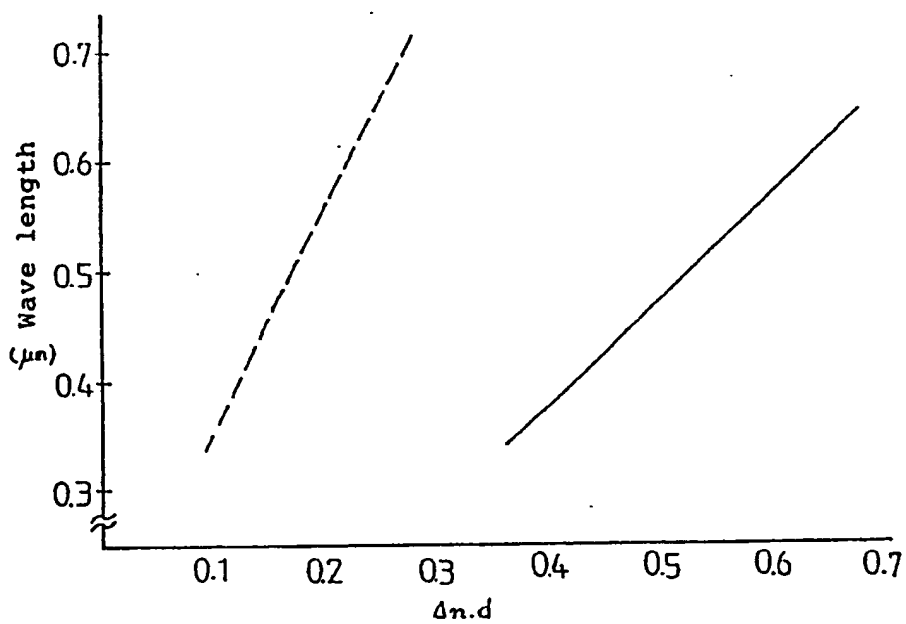


Fig. 16

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/JP89/00707

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (If several classification symbols apply, indicate all) <sup>6</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int. Cl <sup>4</sup>	G02F1/133, 1/135, 1/137	
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>7</sup>		
Classification System	Classification Symbols	
IPC	G02F1/133, 1/135, 1/137	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>9</sup></b>		
Category <sup>9</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
Y	JP, A, 63-115137 (F. Hoffmann-La Roche & CO., A.G.) 19 May 1988 (19. 05. 88) (Family: none)	1 - 3
A	JP, A, 62-299940 (Seiko Epson Corp.) 26 December 1987 (26. 12. 87) (Family: none)	13, 14
Y	JP, A, 57-89724 (Matsushita Electric Ind. Co., Ltd.) 4 June 1982 (04. 06. 82) (Family: none)	1, 5 - 8
P	JP, A, 63-271232 (Seiko Epson Corp.) 9 November 1988 (09. 11. 88) (Family: none)	13, 14
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p><sup>10</sup> Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"Z" document member of the same patent family</p> </div> </div>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search		Date of Mailing of this International Search Report
September 28, 1989 (28. 09. 89)		October 16, 1989 (16. 10. 89)
International Searching Authority		Signature of Authorized Officer
Japanese Patent Office		

Form PCT/ISA/210 (second sheet) (January 1985)